United States Patent [19]

Irwin et al.

[11] **Patent Number: 4,501,285**

[45] **Date of Patent: Feb. 26, 1985**

[54] ULTRASONIC CLEANING APPARATUS

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[21] Appl. No.: **365,569**

[22] Filed: **Apr. 5, 1982**

[51] **Int. Cl.**[3] **B08B 3/12**

[52] **U.S. Cl.** .... **134/58 R**; 134/184; 366/127

[58] **Field of Search** .... 134/1, 58 R, 184; 366/127

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,498,737	2/1950	Holden	366/127 X
3,094,314	6/1963	Kearney et al.	134/1 X
4,064,885	12/1977	Dussault et al.	134/184 X
4,183,011	1/1980	Massa	134/184
4,401,131	8/1983	Lawson	134/184 X

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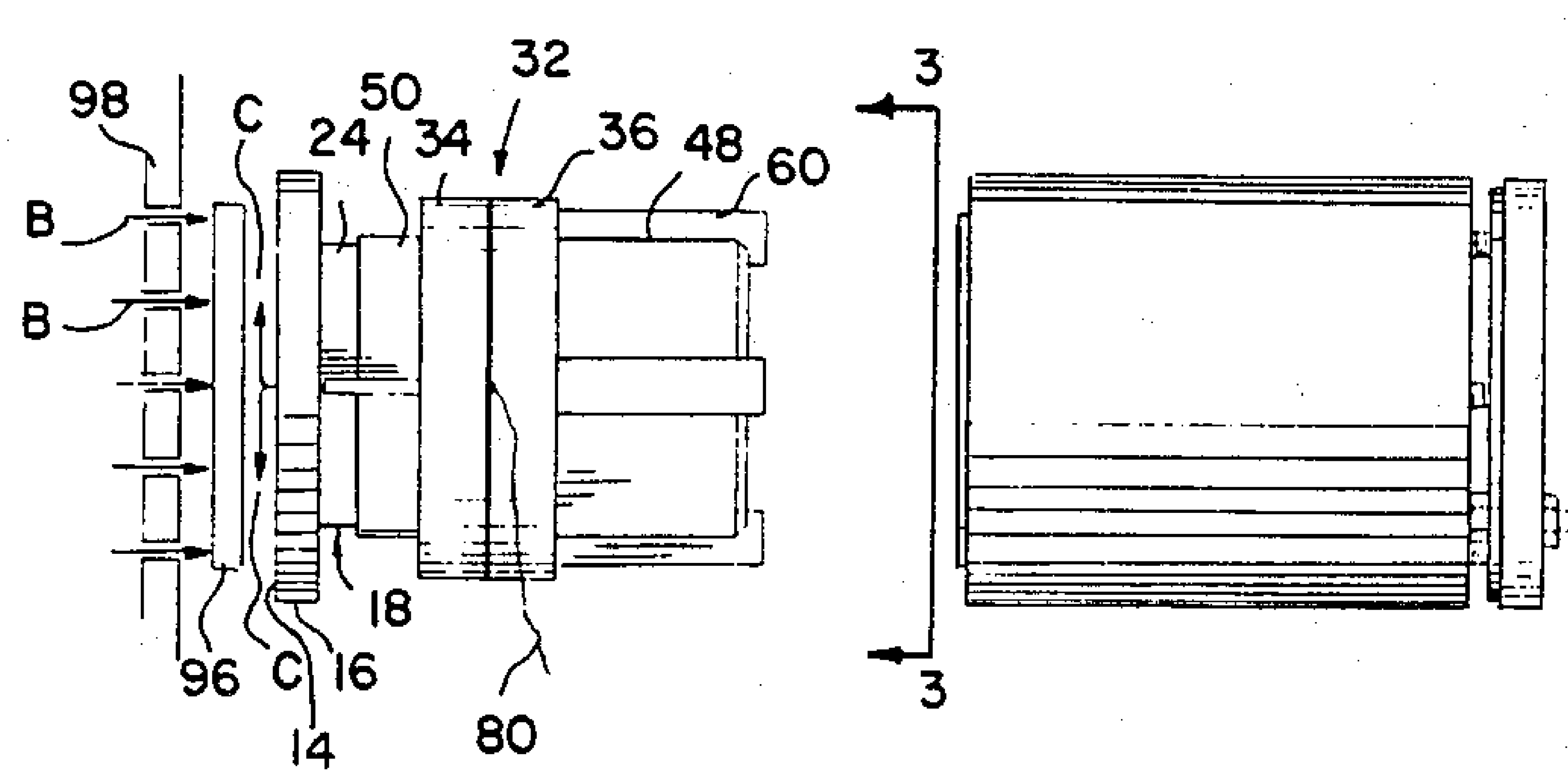
[57] **ABSTRACT**

Ultrasonic transducer apparatus for cleaning applications and method for cleaning wafers of semiconductor material in which the method includes positioning the wafer proximate to but closely spaced away from a cleansing face of the ultrasonic transducer, supplying space between the cleansing face and the wafer with a cleansing fluid through an orifice in the cleansing surface and ultrasonically vibrating the cleansing face transversely to the wafer by applying an electrical signal to piezoelectric material symmetrically disposed about the orifice in the cleansing face via which the cleansing fluid is supplied, with the ultrasonic transducer including piezoelectric material symmetrically disposed with respect to the orifice in the cleansing face through which the cleansing fluid is supplied. The piezoelectric material is preferably in the form of a plurality of discreet piezoelectric elements which are provided with an input signal via a common input terminal where all of the plurality of piezoelectric elements are mechanically coupled to the cleansing face so that the piezoelectric elements, the mechanical coupling structure and a cleansing face ultrasonically vibrate as a single integral structure.

7 Claims, 3 Drawing Figures



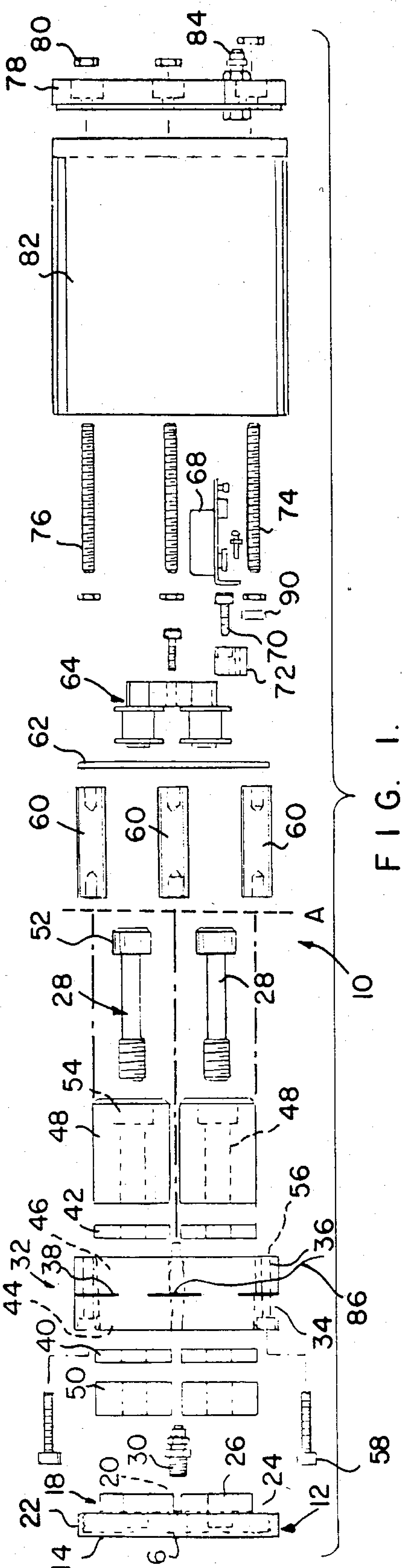


FIG. 1.

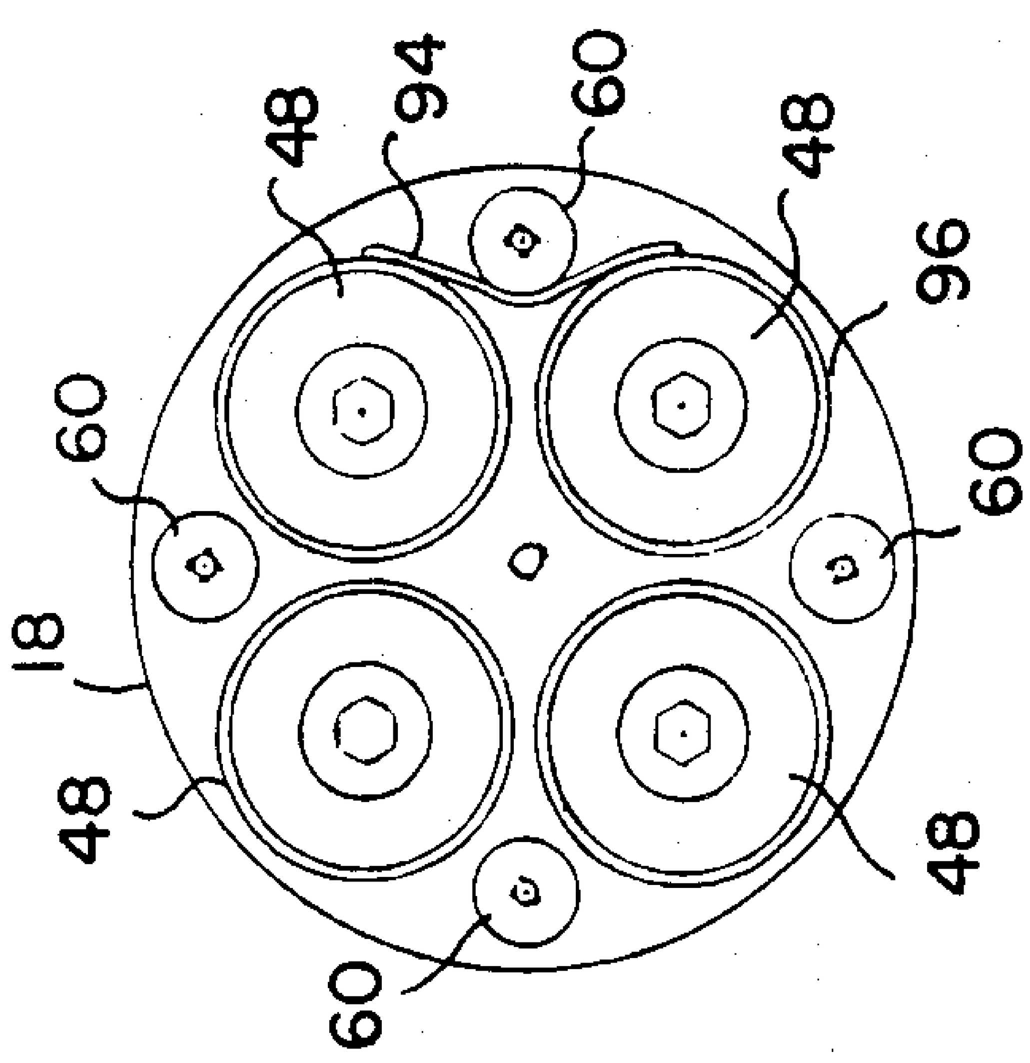


FIG. 3.

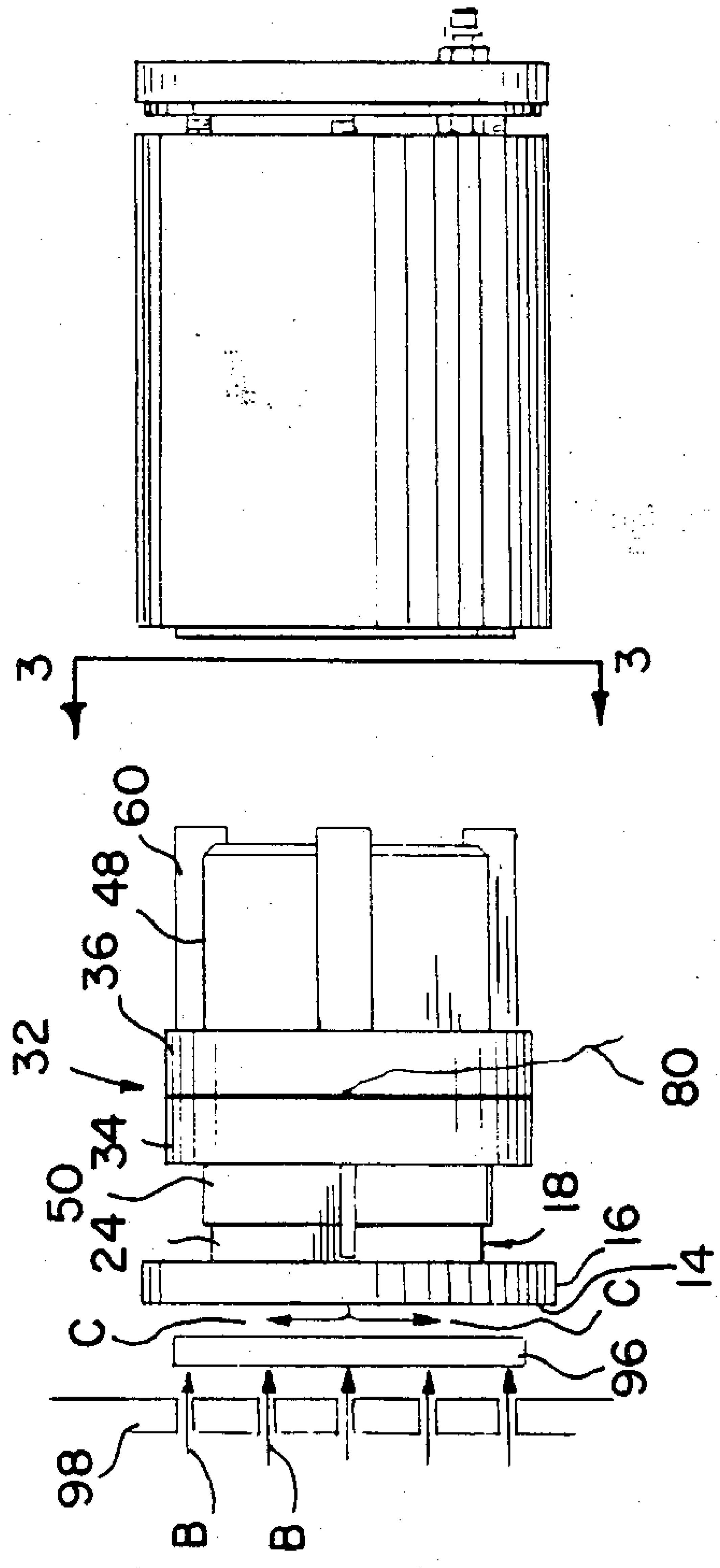


FIG. 2.

ULTRASONIC CLEANING APPARATUS

FIELD OF THE INVENTION

This invention relates to ultrasonic cleaning.

DESCRIPTION OF THE PRIOR ART

U.S. Pat. No. 4,064,885 discloses cleaning semiconductor wafers by supporting the wafer on a rotating shaft and causing liquid solvent to flow continuously across the wafer while the wafer rotates. Ultrasonic energy is applied to the liquid, causing cavitation in the liquid thereby cleaning the wafer.

Other approaches to ultrasonic cleaning have used vibrating tanks or have used transducers at least partially immersed in cleaning liquid in the tank. In the latter case cavitation wear on the immersed ends of the transducers has limited transducer service life to an unacceptably short time.

With growth in electronics, there is high demand for processed semiconductor material from which to manufacture electronic components. For successful processing of the semiconductor material prior to manufacturing the electronic components, the material must be extremely clean. Heretofore there have not been apparatus or methods available which adequately cleaned semiconductor material at a desired rate for economical processing of the semiconductor material prior to the material being incorporated into electronic components. This invention is directed towards solving that problem.

SUMMARY OF THE INVENTION

This invention provides methods and apparatus for ultrasonic cleaning.

Apparatus of the invention includes a cleaning faceplate with a passageway therethrough opening onto a cleansing surface of the faceplate for flow of cleansing process fluid therefrom over the cleansing surface. A conduit communicates with the passageway remote from the cleansing surface opening and supplies the fluid to the passageway. Piezoelectric means convert an electrical input signal into mechanical vibration. Means are provided for mechanically applying the piezoelectric means mechanical vibration to the faceplate symmetrically about the opening of the passageway in a direction transverse to the cleansing surface. Means are provided for supplying electrical input signal to the piezoelectrical means. The faceplate is easily replaceable in the event of faceplate wear. A number of piezoelectric means are mechanically coupled to define a single ultrasonic transducer, where the piezoelectric means are symmetrical about the opening through which the fluid flows.

In one embodiment of apparatus manifesting the invention the ultrasonic transducer for converting electrical energy into mechanical vibratory energy includes a piezoelectric element support assembly having first and second outer sandwich member sandwiching a metallic plate therebetween where the first and second sandwich members each are electrically insulative material and include receptacles for receiving piezoelectric elements therewithin. The receptacles communicate with the plate sandwiched between the first and second sandwich members. The piezoelectric elements reside within the receptacles with each piezoelectric element in contact with the plate. A support plate has a passageway therethrough and supports a faceplate which includes a cleansing surface and a passageway therethrough exiting centrally of the cleansing surface. Means are provided for releasably retaining the faceplate in integral facing contact with the support plate so that passageways through the support plate and the faceplate communicate. The metallic plate provides a common high voltage signal to the piezoelectric elements. The sandwich members are retained together by compression application means and are easily disassembled if replacement of the metallic plate or the input signal wire connection thereto is required.

The support plate and the faceplate can be a single piece.

Preferably, the piezoelectric elements are in pairs with elements of a single pair aligned with respect to a line transverse to the cleansing surface of the faceplate. The piezoelectric element pairs are symmetrical with respect to a longitudinal axis of the passageway through the faceplate exiting centrally of the cleansing surface. The piezoelectric elements are fed from a common terminal.

As used herein in connection with the piezoelectric elements the term "vibrate" refers to the property of those elements whereby when an alternating voltage is applied to an element, the element converts the alternating voltage into a cyclical strain of the same frequency as the alternating voltage. The strain is proportional to the level of the applied voltage.

THE DRAWINGS

FIG. 1 is an exploded side view of transducer apparatus manifesting the invention.

FIG. 2 is a side view of transducer apparatus manifesting the invention in which the outer housing of the transducer apparatus has been displaced to the right and in which cleansing of a wafer of semiconductor material is depicted schematically.

FIG. 3 is a view taken at 3—3 in FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION AND BEST MODE CONTEMPLATED FOR PRACTICE THEREOF

Referring to FIG. 1, transducer apparatus manifesting the invention is designated generally **10** and includes a cleaning faceplate **12** having a preferably circular cleansing surface **14** over which a cleansing process fluid flows. The fluid exhausts through a passageway **16** which extends entirely through faceplate **12**, preferably in a direction generally transverse to cleansing surface **14**. A support plate **18** located immediately behind faceplate **12** includes a passageway **20** which communicates with passageway **16** when support plate **18** and cleansing faceplate **12** facingly contact with plate **18** supporting plate **12**, as depicted in FIG. **1**.

Faceplate **12** includes a circumferential lip **22** extending around faceplate **12** and threads, not numbered in FIG. **1**, which engage corresponding threads formed about the circumference of support plate **18**. The surface of plate **12** opposite cleansing surface **16** is preferably planar as is the facingly contacted surface of plate **18**. Thus, when the respective threads are engaged, plates **18** and **12** are effectively an integral, unitary assembly. The threaded engagement of plate **12** with plate **18** permits rapid replacement of plate **12** when it becomes worn.

Plate **18** further includes lugs **24** extending oppositely from the planar surface which facingly contacts the unnumbered planar back surface of plate **12**, with bores **26** in lugs **24** being internally threaded to receive compression bolts **28**, as described below.

Passageway **20** is internally threaded to receive fitting **30** forming a portion of a conduit for supplying cleansing process fluid to passageway **16** for flow over cleansing surface **14**.

Cleansing faceplate **12** is preferably circularly configured with passageway **16** located at the center of the circular periphery of cleansing surface **14**.

A piezoelectric element support assembly is designated generally **32** and includes respective first and second outer sandwich members **34**, **36** which are electrically insulative material, preferably Micarta. Sandwiched between members **34**, **36** is a terminal spacer plate **38**, which is preferably copper and has outer diameter slightly less than outer diameter of preferably cylindrically configured sandwich members **34**, **36**. First outer sandwich member **34** preferably has a small annular recess therein, at the surface facing second outer sandwich member **36**, for receipt of terminal spacer plate **38**. Both first and second outer sandwich members **34**, **36** are bored to receive preferably cylindrial wafer-like first and second piezoelectric elements **40**, **42** respectively; the bores extending through first and second sandwich members **34**, **36** are denoted **44**, **46** respectively. Bores **44**, **46** pass entirely through their respective sandwich members so that piezoelectric elements **40**, **42** contact terminal spacer plate **38** and receive an electrical input signal therefrom.

Rear bells **48** facingly contact piezoelectric elements **42** within bores **46**, press piezoelectric elements **42** against plate **38** and provide a second electrical connection for piezoelectric elements **42** so that the circuit supplying the input electrical signal to piezoelectric elements **42** may be completed. Rear bells **48** are preferably stainless steel cylinders and are bored, as indicated by the unnumbered, dotted lines, to receive compression bolts **28**. These parts are easily disassembled by removing compression bolts **28** and bolts **58** if repair or replacement of plate **38** or the connection of wire **86** thereto is required.

Forward bells **50**, similarly to rear bells **48**, contact piezoelectric elements **40** at the surfaces thereof opposite terminal plate **38**, urge piezoelectric elements **40** into contact with plate **38** and reside partially within bores **44** formed in first member **34**. Contact between forward bells **50** and piezoelectric elements **40** permits completion of the circuit via which inout signal is supplied to piezoelectric elements **40**. Forward bells **50** are cylindrically configured, are preferably stainless steel and include unnumbered central bores, as indicated by the dotted lines in FIG. **1**.

Assembly of the piezoelectric elements **40**, **42** and their supporting apparatus to cleaning faceplate **12** is accomplished by serially inserting compression bolts **28** through unnumbered longitudinal internal bores in rear bells **48**, in piezoelectric elements **42**, in second outer sandwich member **36**, in terminal spacer plate **38**, in first outer sandwich member **34**, in piezoelectric elements **40**, in forward bells **50** and then threading compression bolts **28** into internally threaded bores **26** formed in lug portions **24** of support plate **18**. Enlarged head portions **52** of compression bolts **28** received by counterbores **54** in rear bells **50** serve to position the shafts of bolts **28** centrally within the unnumbered longitudinal bores of rear bells **48**, piezoelectric elements **42**, second sandwich member **36**, terminal spacer plate **38**, first sandwich member **34**, piezoelectric elements **40**, and forward bells **50**.

The unnumbered central longitudinal bores in piezoelectric elements **40**, **42** and those in terminal spacer plate **38** are slightly larger than outer diameter of the shaft of compression bolt **28** so compression bolt **28** does not contact the interior annular surfaces of the bores through piezoelectric elements **40**, **42** and plate **38** within which bolt **28** resides.

The cylindrical configurations of bores **44**, **46**, piezoelectric elements **40**, **42** and rear and forward bells **48**, **50** serve to align the serial combination of the bells, the piezoelectric elements and the sandwich members about the centerline of the longitudinal central bores passing through these elements. This, in combination with the reduced outer diameter of bolts **28** with respect to the bores internal of piezoelectric elements **40**, **42** and terminal spacer plate **38**, prevents bypass shorting of the circuit via which the input signal is supplied to piezoelectric elements **40**, **42**, as explained below.

Sandwich members **34**, **36** further include communicating bores **56** for passage therethrough of bolts **58** which are received by unnumbered threaded bores in cylindrical, preferably aluminum, spacers **60**. The bolt-spacer combination **58**, **60** serves to connect the assembly of piezoelectric electric elements **40**, **42**, their support members and cleaning faceplate **12** to a mounting plate **62**. A pickup magnet-coil assembly **64** is affixed to mounting plate **62** by a machine screw **66** and a nut, not shown, on the opposite side of plate **62** from screw **66**.

A feedback circuit board **68** is connected to magnet-coil combination **64** via a wire, not shown, and receives a signal from magnet-coil combination **64** which is indicative of the amplitude of vibration of the transducer defined by the integral combination of the elements to left of dash line A in FIG. **1**. Magnet-coil combination **64** is positioned with the magnet bottom sufficiently close to the end of one of rear bells **48** so that as the rear bell **48** vibrates, the magnetic flux in that area changes and the coil portion of the magnet-coil combination **64** senses this change in magnetic flux. Signal from magnet-coil combination **64** is provided to feedback circuit board **68** which in turn provides, via another wire which is not shown, a regulating signal to the power supply which supplies the input signal to piezoelectric elements **40**, **42** via terminal spacer plate **38**. Suitable magnet-coil combinations **64**, feedback circuit boards **68** and power supplies, (not shown) are all within the knowledge of those of skill in the art and, hence, are not further described herein.

A machine screw **70** secures an insulative spacer **72**, preferably manufactured of Delrin, to magnet-coil combination **64**. Feedback circuit board **68** is secured to spacer **72** by screw **74** which passes through a tab of board **68** and into spacer **72**, as indicated by dash lines in FIG. **1**.

Bores in ends of spacers **60** opposite the ends receiving screws **58** are threaded and receive threaded rods **76**, to which a top member **78** is secured by nuts threadedly engaging rods **76**. A cylindrical exterior housing, in conjunction with the cleaning faceplatesupport plate **12**, **18** combination and top **78**, encloses the transducer apparatus.

Top **78** has a fitting **84** to which the flexible conduit from fitting **30** is connected, the conduit not being shown in FIG. **1**. The cleaning process fluid, preferably deionized water, is supplied to this conduit, and hence to cleansing surface **14** via conduit **16**, via fitting **84** which is connected to an external source of cleaning process fluid not illustrated in drawing.

Input signal is provided to terminal spacer plate **38** via a wire **86** which also may pass through a fitting such as **84** in top **78** and is connected to the power supply for the transducer. Wire **86** is, of course, insulated. The other side of the circuit, from the sides of piezoelectric elements **40, 42** which do not contact terminal spacer plate **38**, is provided via forward and rear bells **50, 48** which are commonly connected to support plate **18** via compression bolts **28**. Forward bells **50** are urged against support plate **18** by the compressive action of bolts **28** while rear bells **48** are in contact with the head portions of bolts **28**. Since all bells **48, 50** are connected to support plate **18**, all bells **48, 50** have a common electrical signal applied thereto. Hence the outwardly facing (with respect to terminal spacer plate **38**) faces of piezoelectric members **40, 42** all have a common electrical signal applied thereto. Similarly, the inwardly facing (with respect to terminal spacer plate **38**) faces of piezoelectric elements **40, 42**, all being in contact with terminal spacer plate **38**, have a common input signal applied thereto. Thus all of the piezoelectric elements **40, 42** have the same electrical signal applied simultaneously thereto.

Connection to the side of the circuit opposite that of wire **86** is provided via ground connector **90** which is pressed against a spacer **60** by a nut **92** threadedly engaging one of threaded rods **76**. Good electrical connection between aluminum spacer **60** and two of the rear bells **48** is provided via a spring contact strip **94**, illustrated in FIG. **3**, which is preferably beryllium copper or spring steel and is spring fitted between spacer **60** and two rear bells **48** as illustrated in FIG. **3**.

A suitable insulated wire is connected to ground connector **90**, fed out of the transducer housing via a fitting **84** and connected to the power supply sending the input signal to the transducer. Similarly, feedback signal produced by feedback circuit board **68**, which is indicative of any change required in the amplitude of the input signal supplied via wire **86** by the power supply, may be provided to the power supply for regulation thereof via insulated lead wires exiting the housing via a fitting **84**; such lead wires are not shown to insure the clarity of the drawing.

The symmetrical arrangement of the forward and rear bell-piezoelectric element combinations with respect to the center of circular faceplate **12** and support plate **18** is illustrated in FIG. **3**. Also illustrated in FIG. **3** is the conduit **96** which connects fitting **84** with fitting **30** for supplying the cleaning process fluid to passageway **16** for distribution over the circular cleansing surface **14** of cleaning faceplate **12**.

FIG. **2** illustrates the assembled transducer, but with housing **82** and top **78** moved to the right of arrows **3—3**, to illustrate the transducer internal configuration. In the assembled condition, with bolts **28** securely threaded into bores **26** in lugs **24**, piezoelectric elements **40, 42**, sandwich members **34, 36**, bells **48, 50** and plates **12, 18** are a single integral structure.

When apparatus of the invention is used to clean a wafer **96** of semiconductor material, as in FIG. **2**, the apparatus is configured vertically above wafer **96** and is retained in position by support means, not shown. Wafer **96** is preferably supported by an air cushion, designated by arrows B in FIG. **2**, above a track **98**. Wafer **96** is preferably rapidly rotated during the cleaning process. As the preferred deionized water cleaning process fluid is supplied via conduit **16**, the fluid fills the space between wafer **96** and cleansing surface **14** of cleaning faceplate **12**, as indicated by arrows C in FIG. **2**. Space between cleansing surface **14** and wafer **96** is preferably about 0.035 inches. Cavitation of cleaning process fluid produced by vibration of the transducer, particularly by vibration of cleaning faceplate **12**, provides the cleaning effect of the wafer **96**. The cleaning process fluid is preferably continuously supplied, to carry away debris removed from wafer **96** during the cleaning process.

The threaded connection of cleaning faceplate **12** and support plate **18** permits rapid replacement of cleaning faceplate **12** when cleansing surface **14** becomes worn. This is highly desirable since cleaning faceplate **12**, which may be made of aluminum, may wear out very quickly—in a relatively few hours. Connection means other than threads may also be used; it is desirable that the connection means facilitate rapid replacement of a worn faceplate. As yet another alternative, faceplate **12** and support plate **14** may be a single integral member.

Front and rear bells **50, 48** in combination with compression bolts **28** apply pressure on the piezoelectric crystal elements **40, 42** so that the piezoelectric elements **40, 42** are maintained in proper compression. If pressure is too high, piezoelectric elements **40, 42** cannot vibrate. Conversely, if pressure is too low piezoelectric elements **40, 42** will self destruct as they vibrate when electrical signal is applied thereto. Suitable piezoelectric elements **40, 42** are available from Channel Industries.

Length of the forward and rear bells **50, 48** is a function of the selected design frequency.

Connecting wire **86** is preferably looped through a hole in plate **38** and then soldered thereto, assuring good electrical connection.

The configuration of the piezoelectric element support assembly **32** effectively permits four subtransducers, each defined by an axially aligned combination of first and second piezoelectric elements **40, 42** and the forward and rear bells **50, 48** in contact therewith to operate in phase with one another from a common high voltage provided via terminal spacer plate **38**. This configuration permits rapid repair and/or replacement of piezoelectric elements **40, 42** and the electrical connections thereto provided by forward and rear bells **50, 48** and terminal spacer plate **38**. With this configuration of the piezoelectric element support assembly, the apparatus of the invention works as a single transducer, having multiple piezoelectric elements, which work in unison due to their common high voltage contact. Similarly, common feedback provided by feed of signal from all of forward and rear bells **50, 48** to a common, single feedback circuit is sufficient to regulate the amplitude of vibration of the transducer. Multiple feedback circuits are not required to match the subtransducers to the load because all of the axially aligned piezoelectric element combinations work in unison one with another thereby defining a single, large transducer operating in response to a single input signal.

When apparatus manifesting the invention is assembled, compression bolts **28** may be tightened to specific torque to achieve desired pressure on the piezoelectric elements **40, 42**. Alternately, the parts may be held in a hydraulic press, set to a preselected pressure, while the bolts are tightened.

In the preferred embodiment of the invention, the transducer is designed to operate at a 20,000 Hz nominal frequency, with a tolerance of ±1,000 Hz. Pressure of 9,000 psi is applied to the piezoelectric elements **40, 42.** Piezoelectric element pressures from about 7,000 psi to about 12,000 psi are permissible.

the symmetric arrangement of the "subtransducer" elements (defined by a single forward bell **50**-piezoelectric member **40**-piezoelectric member **42**-rear bell **48** sandwich) about passageway **16** and with respect to circular cleansing surface **14** assures that cleaning faceplate **12** vibrates substantially uniformly, transversely to cleansing surface **14.**

We claim:

1. An ultrasonic transducer for cleaning applications, comprising:

a. a support plate including a passageway therethrough proximate the central portion thereof;
b. a faceplate including a cleansing surface and a passageway therethrough exiting centrally of said cleansing surface;

wherein said support plate passageway and said faceplate passageway communicate and said support plate facingly contacts said faceplate to support same;

c. means for releaseably retaining said faceplate in integral facing contact with said support plate with said passageways in fluid communication;
d. a conduit in fluid communication with said passageways for supplying cleansing fluid to said cleansing surface of said faceplate via said faceplate and support plate passageways;
e. piezoelectric means for converting an electrical input signal to vibrational mechanical energy;
f. means for mechanically coupling said piezoelectric means to said support plate;
g. means for adjustably mechanically compressing said piezoelectric means within a preselected pressure range;
h. sensor means for measuring amplitude of vibration of said piezoelectric means;
i. means for supplying said electrical input signal to said piezoelectric means; and
j. feedback circuit means, receiving from said sensor means a signal indicative of amplitude of vibration of said transducer, for regulating amplitude of signal input to said piezoelectric means by said signal supplying means.

2. An ultrasonic transducer for cleaning operations, comprising:

a. a piezoelectric element support assembly including:
   i. first and second sandwich members;
   ii. a metal plate sandwiched between
      said first and second members; wherein said first and second members are electrically insulative and include receptacles for receiving piezoelectric elements therein, said receptacles communicating with said plate sandwiched between said first and second members;
   iii. piezoelectric elements within said receptacles, each piezoelectric element contacting said plate;

wherein said piezoelectric elements and said plate have corresponding communicating clearance holes therethrough;

b. a support plate having a passageway therethrough;
c. a faceplate including a cleansing surface and a passageway therethrough exiting centrally of said cleansing surface;
d. means for releasably retaining said faceplate in integral facing contact with said support plate so said support plate and said faceplate passageways communicate;
e. a conduit, communicating with said communicating passageways of said support and faceplates, for supplying cleansing fluid to said cleansing surface of said faceplate via said support and faceplate communicating passageways;
f. means for retaining said piezoelectric elements in contact with said metal plate and mechanically coupling said piezoelectric elements to said support plate for unitary vibration thereof upon application of an input electrical signal to said piezoelectric means; and
g. means for supplying an electrical input signal to said piezoelectric elements via said metallic plate.

3. The transducer of claim **2**, wherein said piezoelectric elements are disposed symmetrically with respect to an axis passing through an orifice defining the exit of said passageway in said cleansing surface.

4. The transducer of claim **3**, wherein said piezoelectric elements are disposed in two strata, each stratum being arranged symmetrically with respect to said axis.

5. The transducer of claim **4**, wherein said piezoelectric elements are arranged in pairs symmetrically with respect to said axis, with the two elements defining each pair being aligned, lines of pair alignment being parallel with said axis through said orifice.

6. An ultrasonic transducer for converting electrical energy into mechanical vibratory energy, especially adapted for cleaning operations, comprising:

a. a piezoelectric element support assembly including:
   i. a first outer sandwich member;
   ii. A second outer sandwich member;
   iii. a metal plate sandwiched between
      said first and second members; wherein said first and second members each are electrically insulative material and include receptacles for receiving piezoelectric elements therein, said receptacles communicating with said plate member sandwiched between said first and second insulative members;
   iv. piezoelectric elements resident within said receptacles, each piezoelectric element in facing contact with said plate;

wherein said piezoelectric elements and said plate have corresponding communicating clearance holes therethrough;

b. a support plate having passageway therethrough;
c. a faceplate including a cleansing surface and a passageway therethrough terminating in an orifice centrally of said cleansing surface;
d. means for releasably retaining said faceplate in integral facing contact with said support plate so that said support plate and faceplate passageways communicate;
e. a conduit in fluid communication with said communicating passageways of said support and faceplates, passing through a central bore in said piezoelectric element support asembly, including a threaded fitting at an outlet thereof engaging a threaded receptacle defining at least a portion of said passageway through said support plate, for supplying cleansing fluid to said cleansing surface of said faceplate via said communicating passagways of said support and faceplates;
f. forward bell means in facing contact with said piezoelectric means residing within one of said sandwich members, an opposite side thereof in

facing contact with said support plate, for transmitting mechanical vibration of said piezoelectric means to said support plate and hence to said faceplate;

g. rear bell means facingly contacting piezoelectric means residing within said remaining sandwich member, said rear bell means being of selected length to define selected frequency of said transducer;

wherein said forward and rear bell means include bores therethrough communicating with corresponding bores through said piezoelectric means, said metal plate and said sandwich members;

h. means passing serially through said rear bell means, a piezoelectric element within said second sandwich member, said plate, a piezoelectric element within said first sandwich member, said forward bell means and received by said support plate, for applying pressure to said piezoelectric elements and for retaining said forward and rear bells, said piezoelectric element support assembly and said support plate in integral, unitary disposition;

i. a magnet-coil combination for sensing changes in magnetic flux density as said rear bell vibrates unitarily with said piezoelectric members, for measuring said flux density changes and producing an electrical signal indicative thereof;

j. feedback circuit means receiving the signal from said magneti-coil combination for regulating amplitude of a signal supplied by a power supply to said piezoelectric means; and

k. said power supply furnishing an electrical input signal to said piezoelectric elements via said metal plate.

7. An ultrasonic cleaning transducer comprising:

(a) a faceplate having orifice means therein opening centrally and symmetrically onto a faceplate cleansing surface for flow of cleansing process fluid therefrom over said cleansing surface;

(b) means for supplying said fluid to said orifice means;

(c) piezoelectric means for converting an electrical signal into mechanical vibration and vibrating said faceplate;

wherein said orifice exits centrally and symmetrically onto said cleansing surface; and further comprising:

(d) means for mechanically coupling said piezoelectric means to said faceplate;

(e) means for adjustably compressing said piezoelectric means within a preselected pressure range;

(f) means for measuring amplitude of vibration of said piezoelectric means;

(g) means for supplying said electrical signal to said piezoelectric means; and

(h) feedback means, receiving from said measuring means a signal indicative of amplitude to vibration of said transducer, for regulating signal amplitude input to said piezoelectric means by said signal supplying means.

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